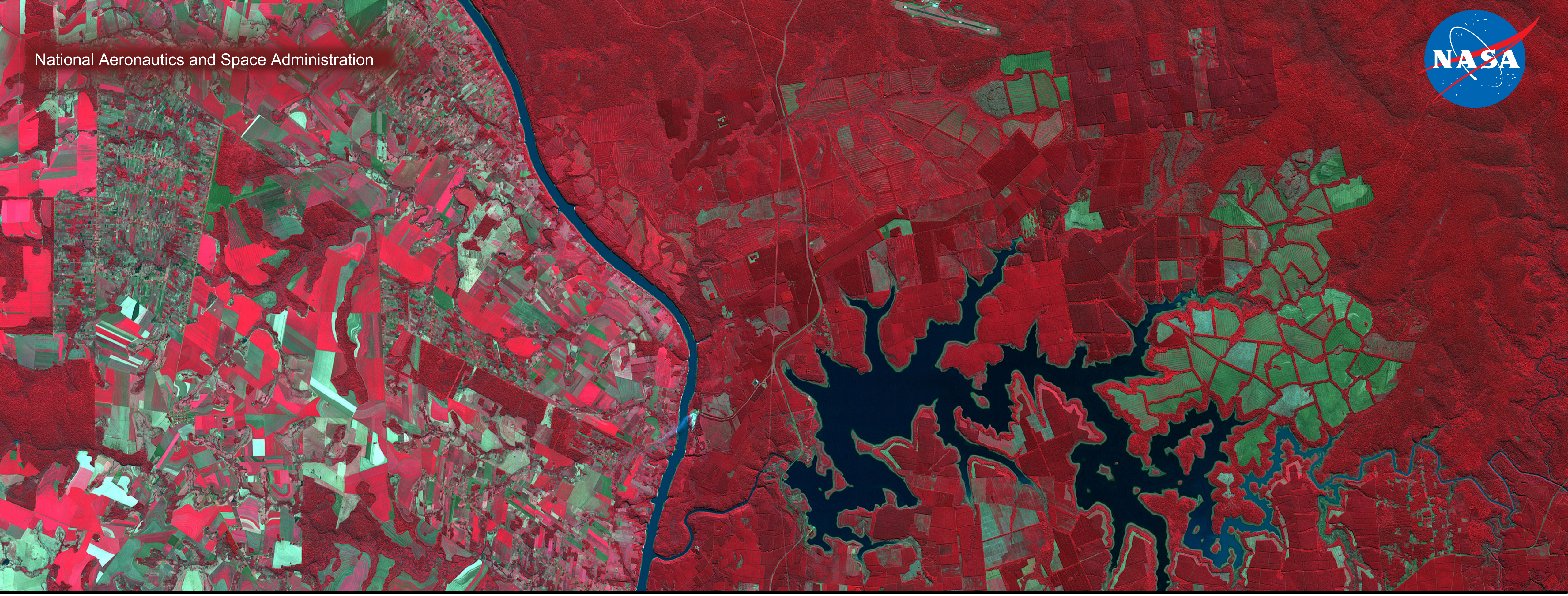


Analysis of Fresh Water Components: Precipitation, Soil Moisture, ET, and Runoff over the SFV watershed

Amita Mehta

4 December 2017

APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Objectives

By the end of this exercise, you will be able to analyze surface fresh water components over the SFV watershed for a recent month (September 2017) using Giovanni and Earthdata portals, and QGIS

Requirements

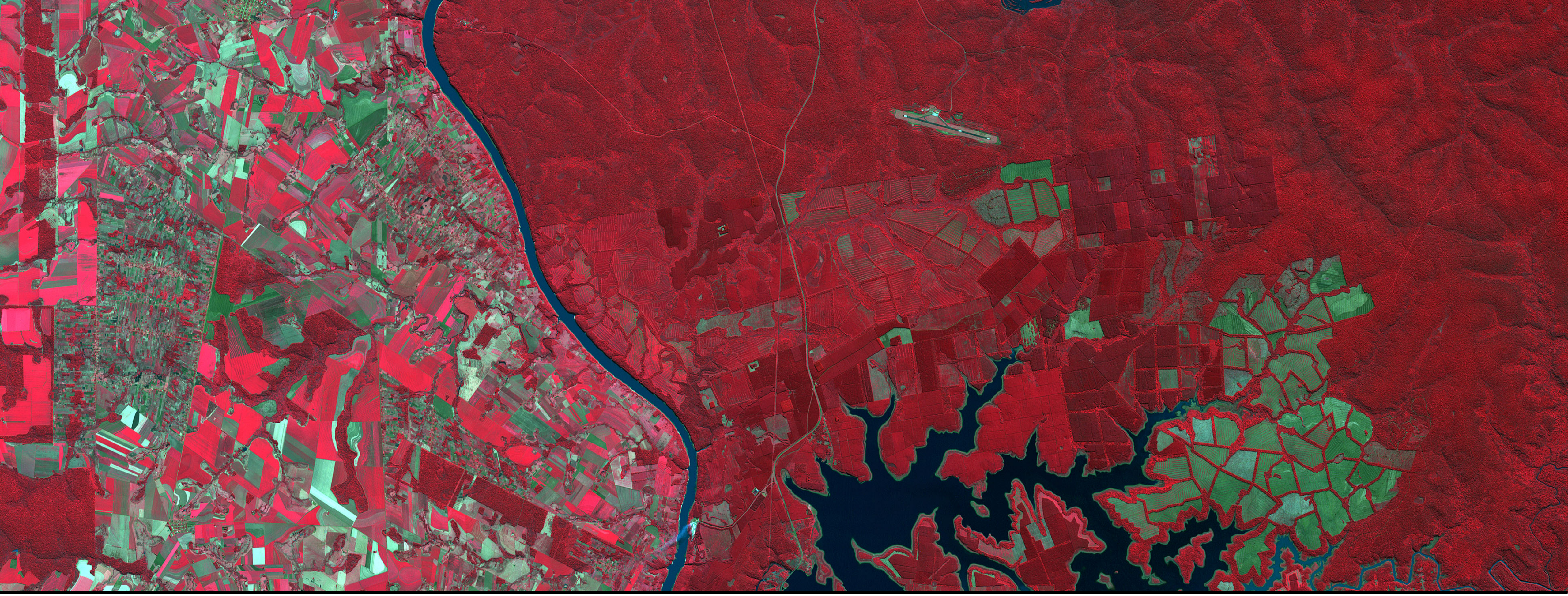
- QGIS installed on your computer
  - https://arset.gsfc.nasa.gov/sites/default/files/water/drought/Introduction%20to%20QGIS.pdf
- A shapefile for the Sao Francisco Verdadeiro (SFV) watershed saved on your computer
  - http://arset.gsfc.nasa.gov/

Note

- This is a two-part exercise where you will use some of the same data products and QGIS analysis techniques you have used so far to obtain freshwater components
- Part 1 will focus on the SFV watershed and examine GPM-IMERG precipitation, SMAP-soil moisture, GLDAS Runoff and ET, for September 2017.
- Part 2 will be conduced in groups of 5-6 persons
  - each group will focus on a watershed or area of their choice and conduct the same analysis for the month of their choice
- At the end of the second part each group will provide presentations of results

Part 1 Outline

- For the SFV watershed in September 2017
  – Subset and Download GPM IMERG Precipitation Using Giovanni
  – GLDAS Runoff and ET using Giovanni
  – SMAP Soil Moisture form Princeton Latin American Flood & Drought Monitor (http://stream.princeton.edu/LAFDM/WEBPAGE/)
- Obtain Monthly Accumulated Freshwater Components using QGIS
- Discussion



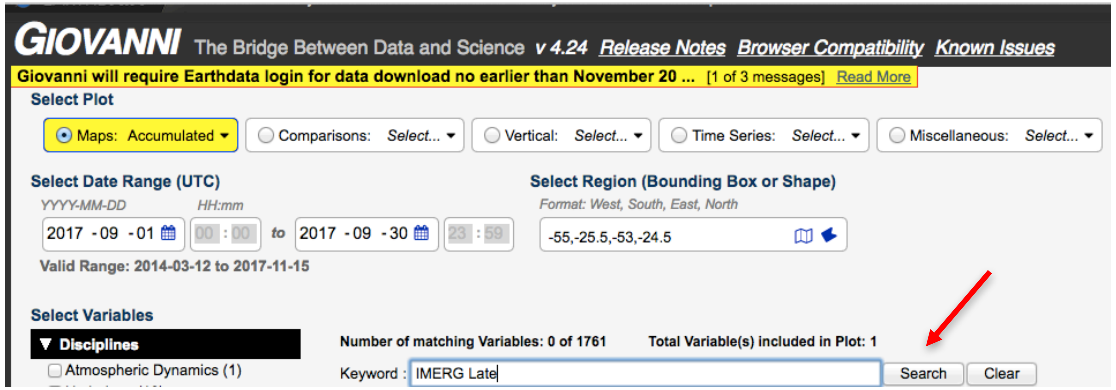
Subset and Download GPM IMERG Precipitation

Subset GPM IMERG Precipitation

1. Go to Giovanni: http://giovanni.gsfc.nasa.gov/giovanni
2. On the Giovanni page you will see the following options:
   - **Select Plot:** allows selection of analysis options
   - **Select Data Range:** allows selection of a time period
   - **Select Region (Bounding Box or Shapefile):** allows selection of a geographic region by latitude-longitude, map, or shapefile
   - **Keyword:** allows search of data parameters by keyword
   - **Plot Data:** (located on the bottom right of the page) begins the action to make a desired plot

Subset GPM IMERG Precipitation

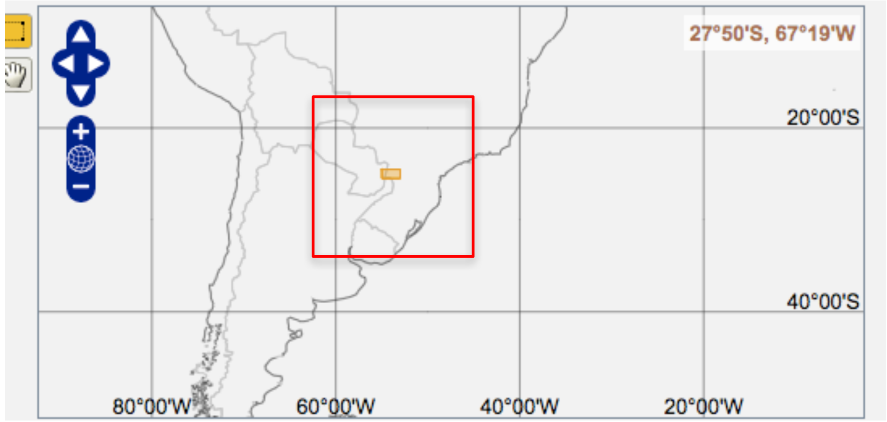
3. Enter the following options:
   - Next to **Keyword**
     - Enter IMERG Late. Click **Search**
     - Select **Dailyaccumulated precipitation (Combined microwave-IR) estimate-Late Run (GPM_3IMERGDL v04)**

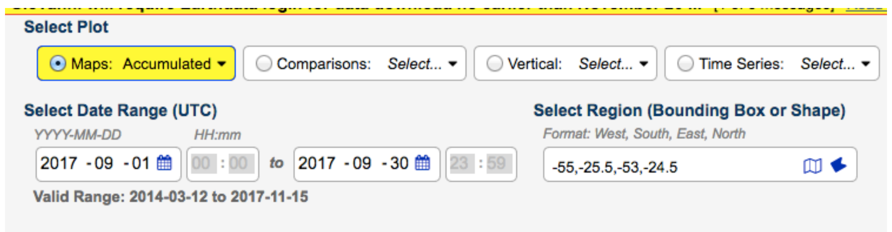


✓	Daily accumulated precipitation (combined microwave-IR) estimate - Late Run (GPM_3IMERGDL v04)	GPM	Daily	0.1 °	2014-03-12	2017-11-29	mm

Subset GPM IMERG Precipitation

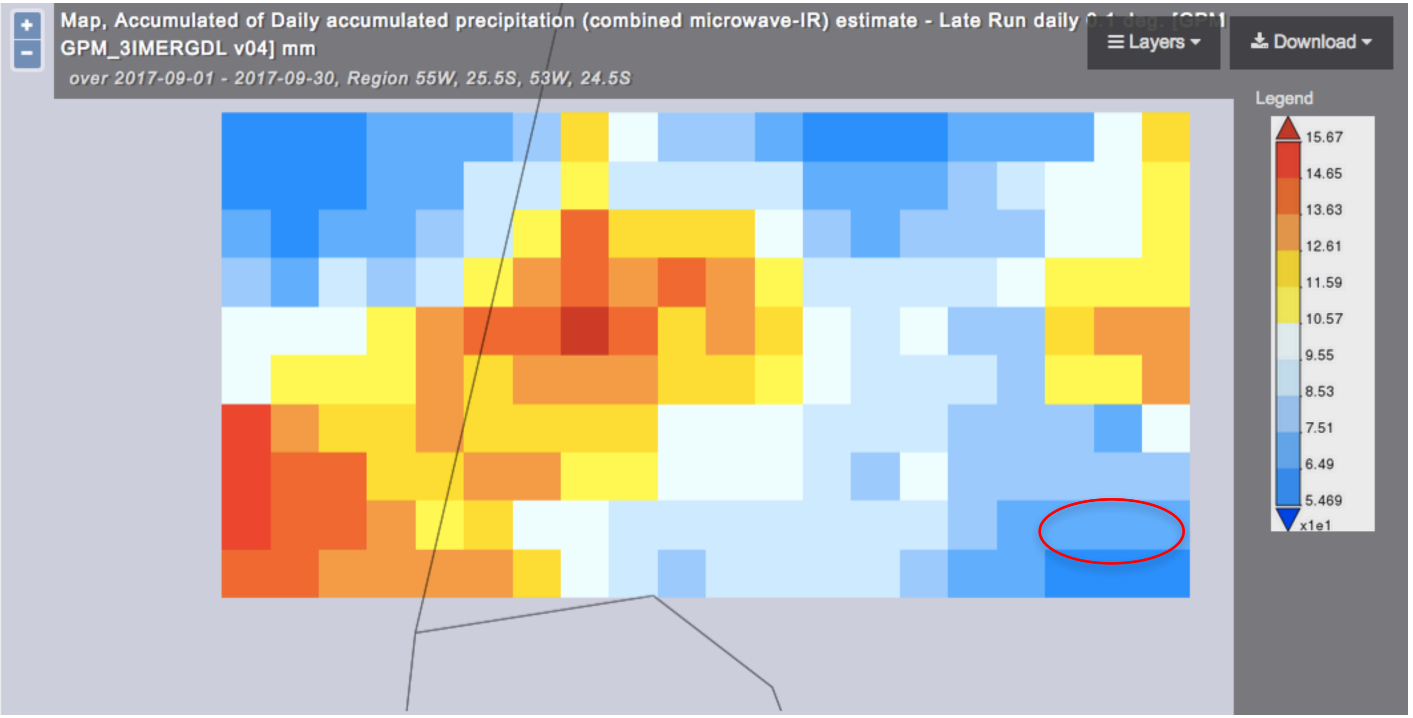
- Under Select Plot Select **Maps: Accumulated.**
- Under Select Region (Bounding Box or Shape)
  - Enter the longitude-latitude around the SFV: -55.0, -25.5, -53.0, -24.5
  - Note: west longitudes and south latitudes are negative, whereas east longitudes and north latitudes are positive
  - Click on the map icon to see the region
- Under Select Date Range (UTC)
  - In the **YYYY-MM-DD** windows, enter **2017-09-1** to start and **2017-09-30** for the end date





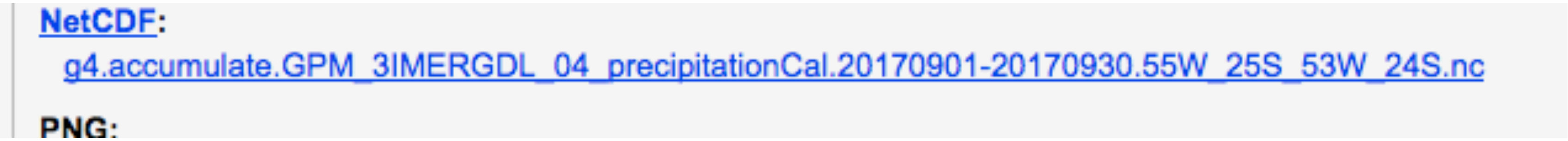
Subset GPM IMERG Precipitation

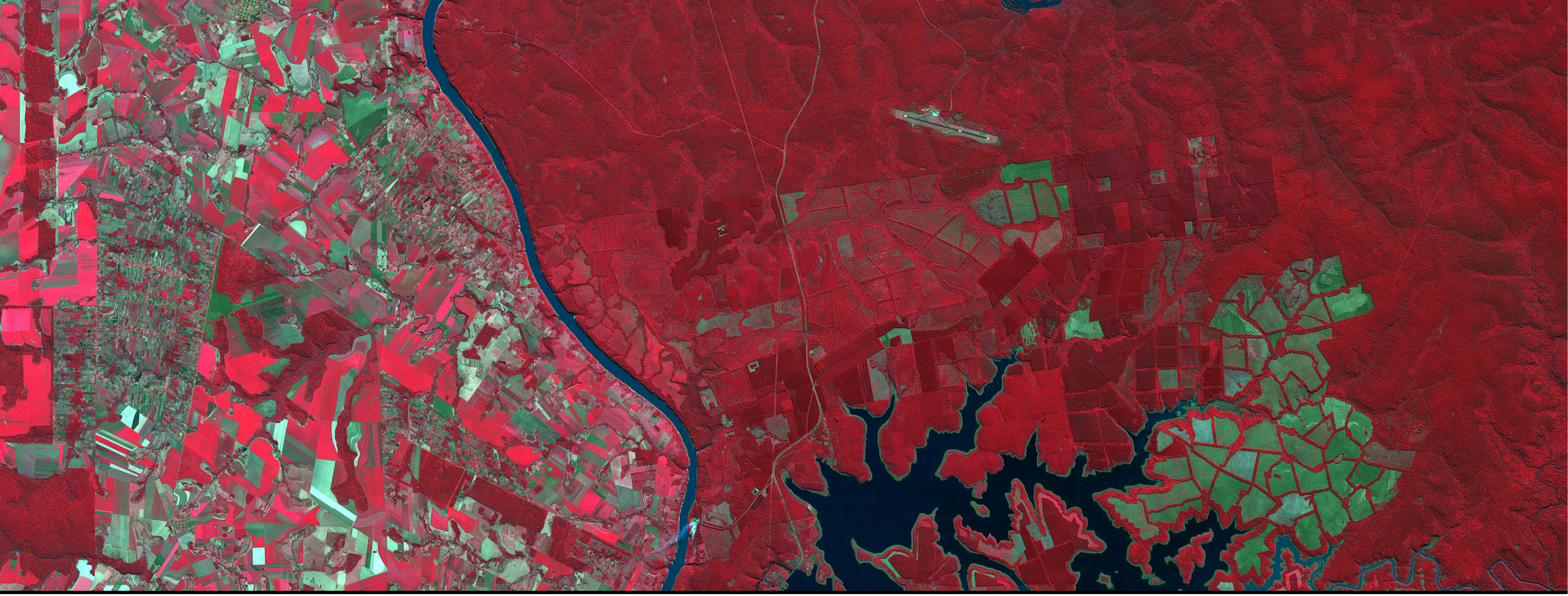
- Click on **Plot Data** (on the bottom right of the screen)
- You will get the map of accumulated precipitation for September 2017 below



Download GPM IMERG Precipitation

1. Click on the **Downloads** link on the left, and you will see multiple file options. Choose the NetCDF file by clicking on the link to save the file to your computer for later use in QGIS
   - Suggestion: Create a folder named 'Final-SFV' and save the September 2017 file in the folder. Suggest to rename the long Giovanni NetCDF file to IMERG_Sep2017

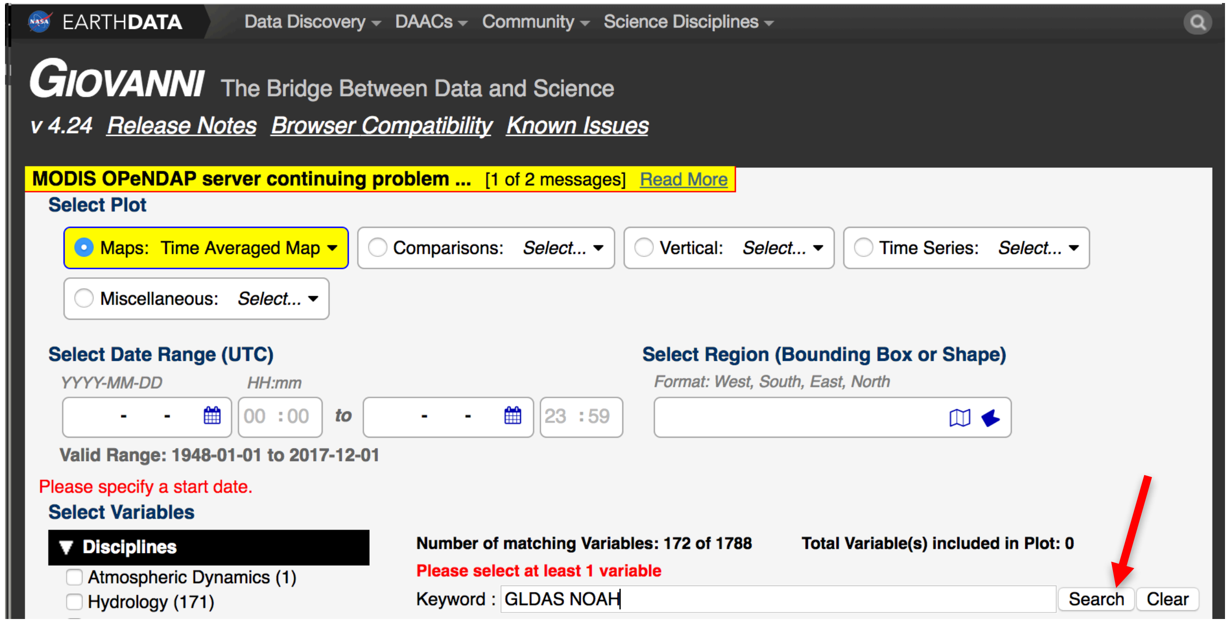


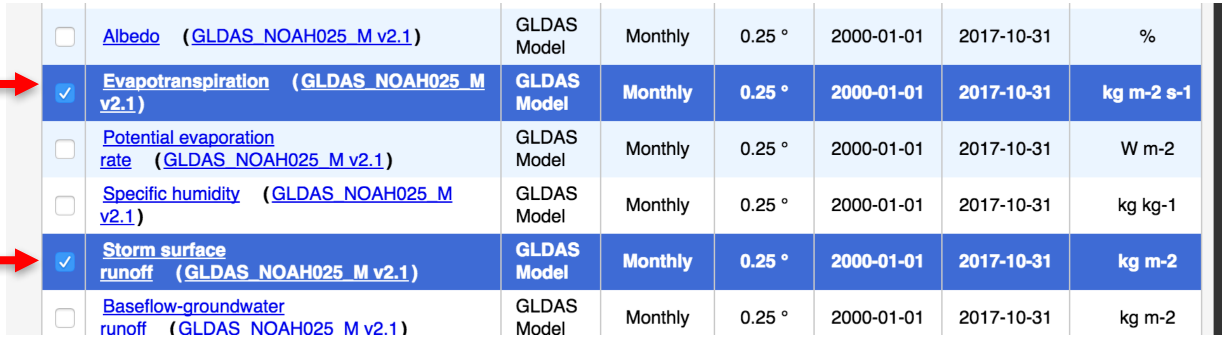


Subset and Download GLDAS Runoff and ET

Subset and Make Monthly Runoff and ET Map

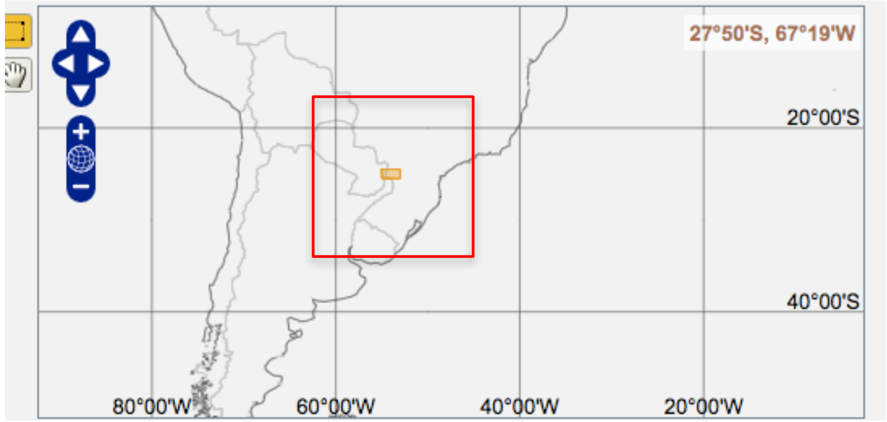
1. Enter the following options:
   - Next to **Keyword**
     - Enter GLDAS NOAH. Click **Search**
     - You will get a list of parameters
     - Select **Evapotranspiration (GLDAS_NOAH025_Mv2.1) and Strom surface runoff (GLDAS_NOAH025_Mv2.1) Monthly**

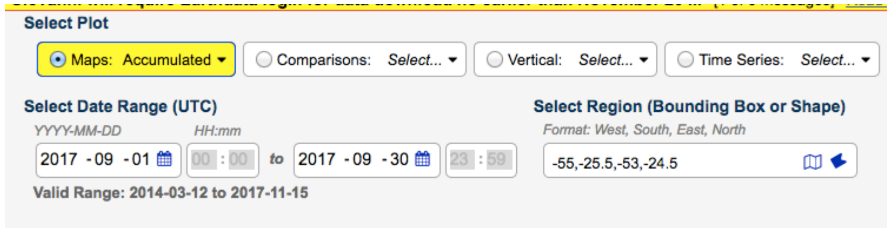




Subset and Make Monthly Runoff and ET Map

– Under Select Plot
  - Select **Maps: Time Averaged Map**
– Under Select Region (Bounding Box or Shape)
  - Enter the longitude-latitude around the SFV:
    -55.0, -25.5, -53.0, -24.5
  - Note: west longitudes and south latitudes are negative, whereas east longitudes and north latitudes are positive
  - Click on the map icon to see the region

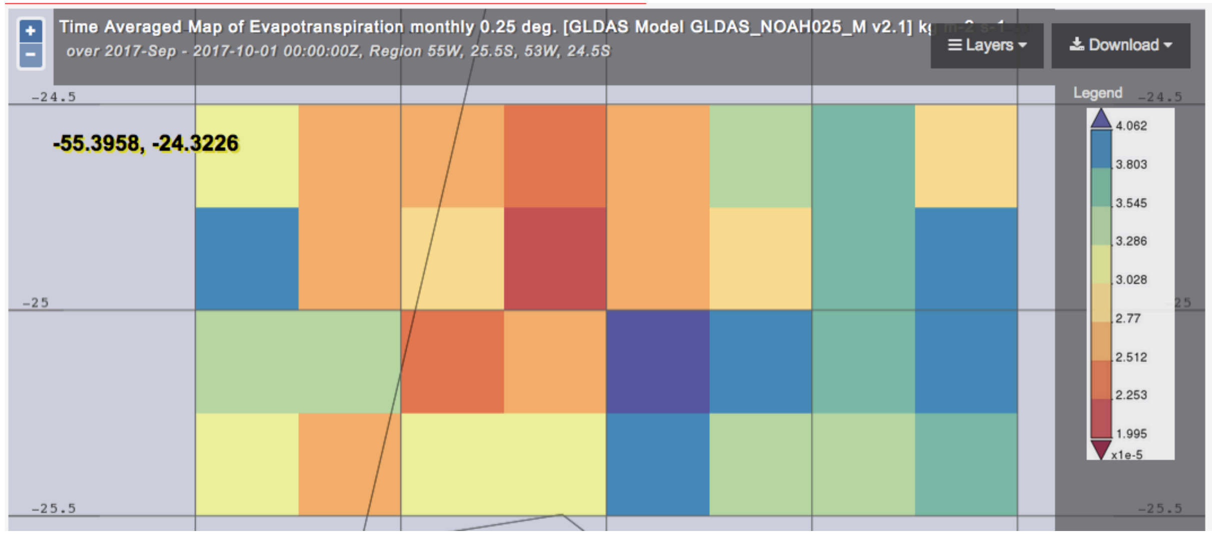


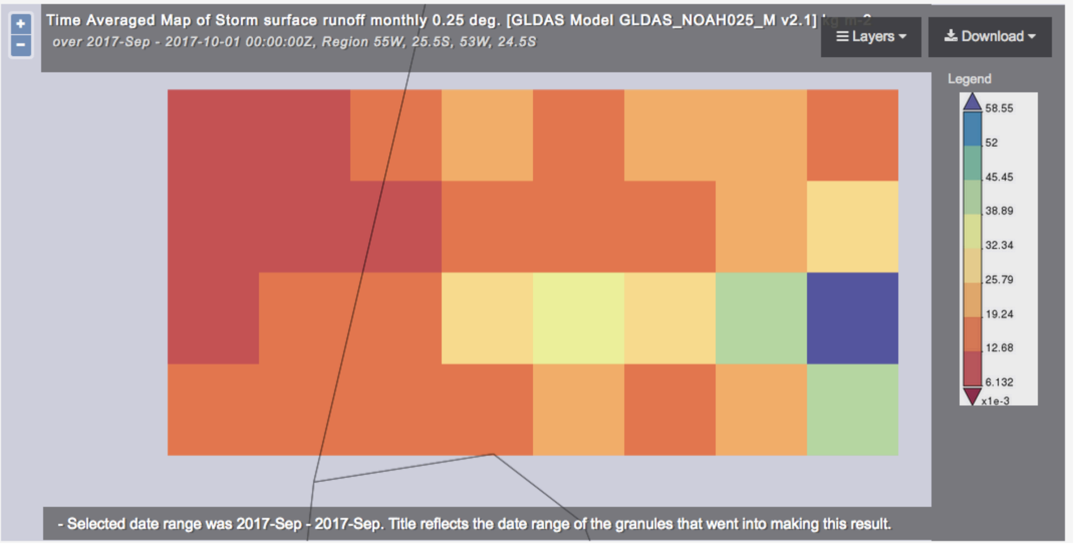


Subset and Make Monthly Runoff and ET Map

- Under Select Date Range (UTC)
  - In the YYYY-MM-DD windows, enter 2017-09-1 to start and 2017-09-30 for the end date

2. Click on **Plot Data** (on the bottom right of the screen)
   - You will get the maps below of ET and Runoff for September 2017

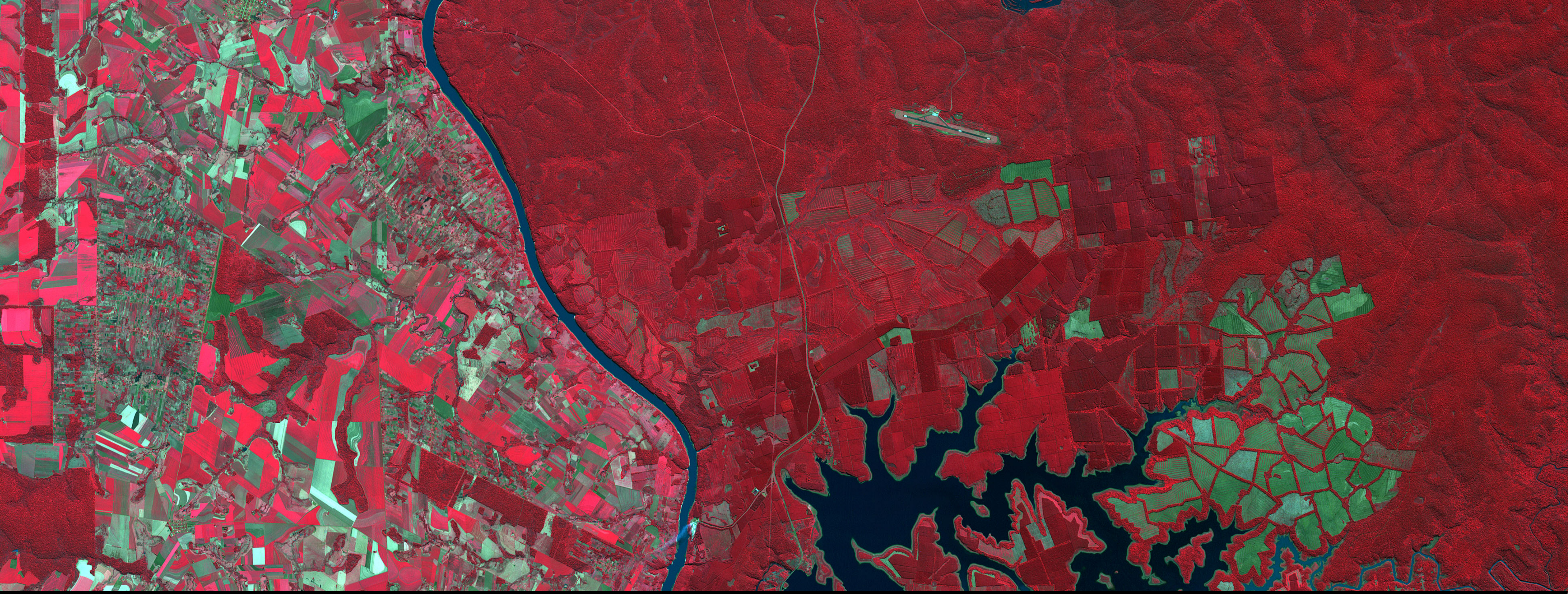




Download ET and Runoff Data

3. Click on the **Downloads** link on the left. You will see multiple file options. Choose the NetCDF files for ET and Runoff by clicking on the link to save the files to your computer for later use in QGIS
   – Save the files in the same folder ("Final-SFV") where your precipitation files are saved
   – Suggestion: rename the long Giovanni NetCDF file to ET_Sep2017 and Runoff_Sep2017

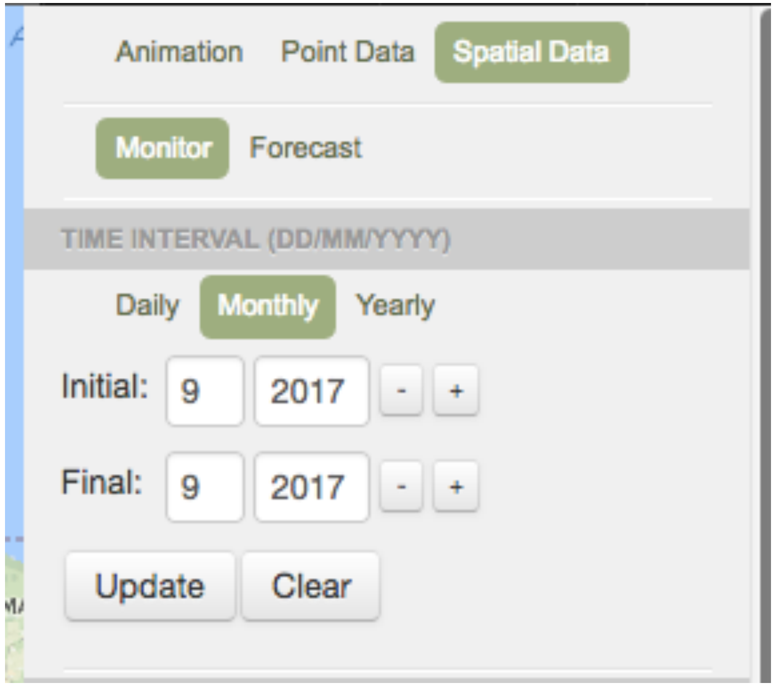
NetCDF:
g4.timeAvgMap.GLDAS_NOAH025_M_2_1_Evap_tavg.20170901-20170930.55W_25S_53W_24S.nc
g4.timeAvgMap.GLDAS_NOAH025_M_2_1_Qs_acc.20170901-20170930.55W_25S_53W_24S.nc



Subset and Download SMAP Soil Moisture

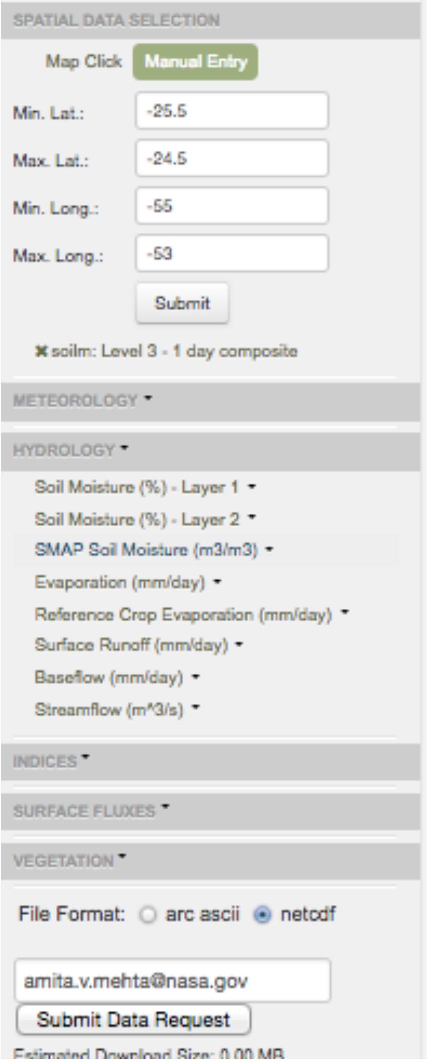
Subset SMAP Soil Moisture Data

1. Go to
   http://stream.princeton.edu/LAFDM/WEBPAGE/
   - Click on **Proceed to Website**
2. You will see the map and a panel on the right-hand side for data selection and subsetting
   - Select **Spatial Data**
   - Select **Monitor**
   - In **TIME INTERVAL (DD/MM/YYYY)** choose **Monthly**, and for **September 2017**, choose:
     - **Initial:** 9 and 2017
     - **Final**: 9 and 2017



Subset SMAP Soil Moisture Data

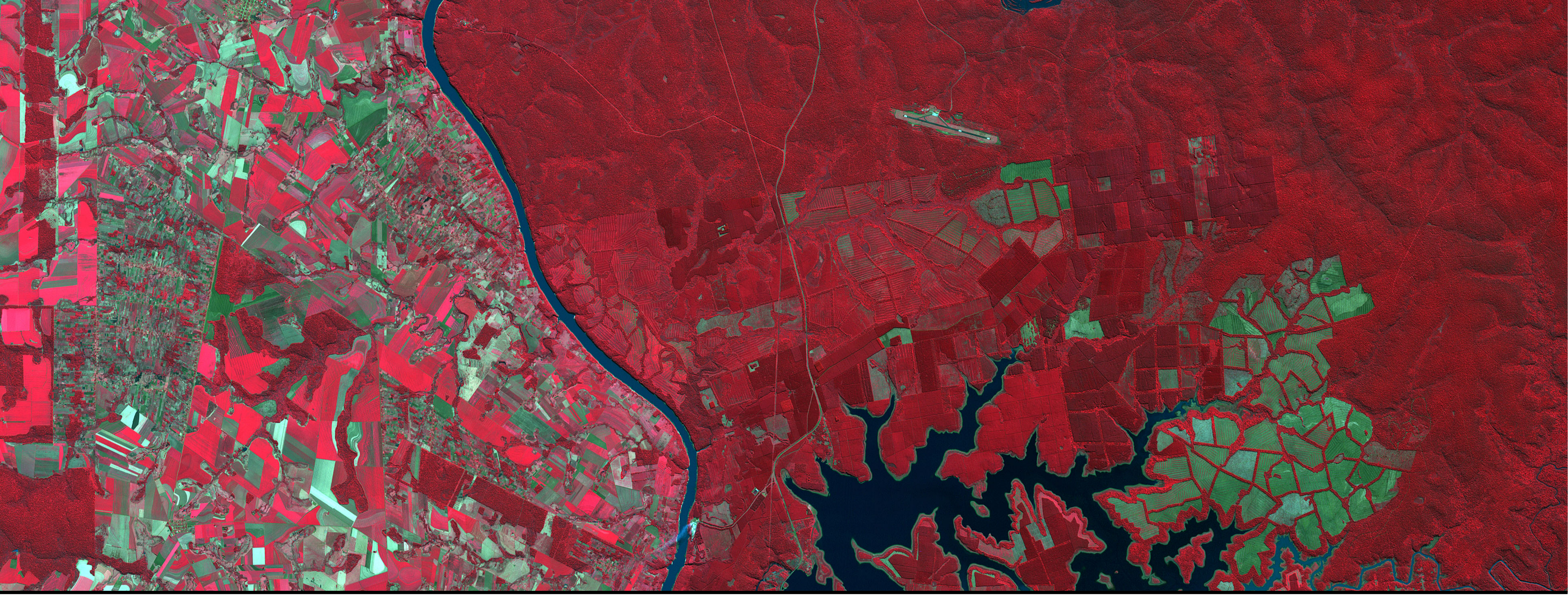
3. Under **SPATIAL DATA SELECTION** choose **Manual Entry**
   – Min Lat: -25.5, Max Lat: -24.5, Min Long: -55, Max Long: -53
4. Click on **Submit**. You will see the selected area on the map
5. Scroll down and select **Hydrology** > **SMAP Soil Moisture (m3/m3)** > **Level 3-1 Day Composite**
6. Scroll down to **File Format** and select **netcdf**
7. Enter your email address in the box and click **Submit Data Request**



Subset SMAP Soil Moisture Data

- You will get an email with a link to download a .zip file for the area and time you selected
- Save the file in the same folder as your precipitation, runoff, and ET data
- Unzip the file and you will get the soil moisture map

Note: the soil moisture data from Princeton Latin America Flood and Drought Monitor have a resolution of 0.25 x 0.25 degrees



Obtain Monthly Accumulated Freshwater Components Using QGIS

Note

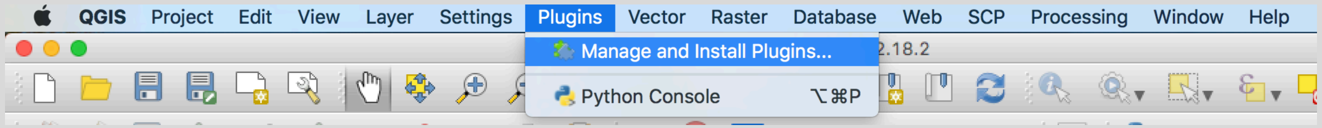
- Rain, ET, Runoff, and Soil Moisture data are the main freshwater components of a watershed
- The freshwater data we are using have different spatial resolutions & units:
  - Rainfall 0.1 degree (~10 km) mm/month
  - ET, Runoff, Soil Moisture 0.25 degree (~25 km) kg/m^2,(kg/m^2) per second
  - Soil Moisture 25 km m^3/m^3 respectively
- We will resample all the datasets at 0.1 degree resolution to match the rain data
- Recall that the rain data are in terms of accumulation over a month where the other data are monthly averages
- We will convert all the units to mm/month (equivalent to kg/m^2 per month) to match the rain data

Freshwater Components Analysis in QGIS

1. Open QGIS and start a new project
2. On the top menu bar, click on **Web** to check if you have **OpenLayers Plugin**

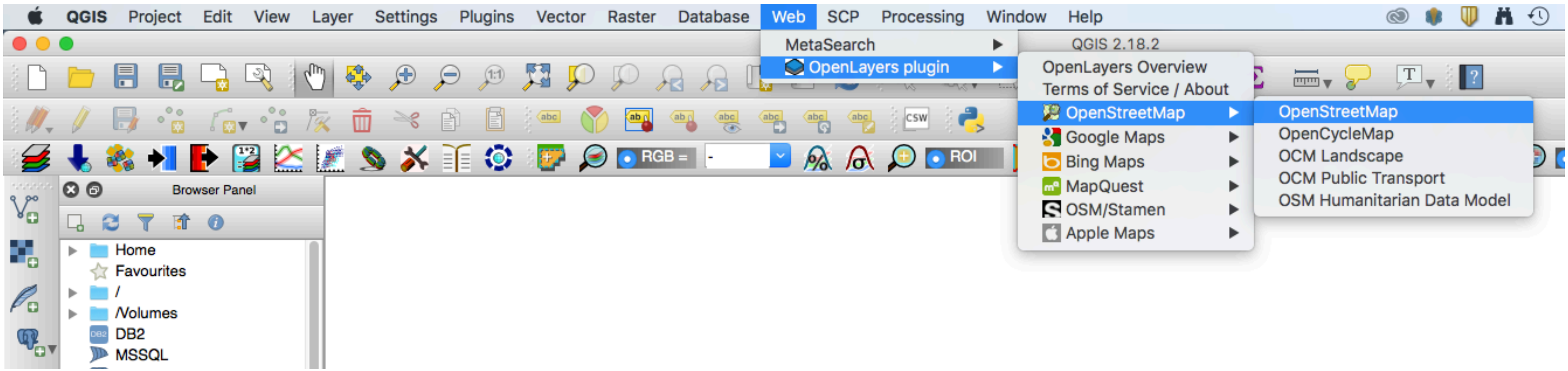
If you do not have the OpenLayers Plugin

- Select **Plugins** from the top menu, and choose **Manage and Install Plugins**
- You will get a window with options for Plugins
- Enter OpenLayers in the search window
- Clicking on the **OpenLayers Plugin** and press **Install** in the bottom right



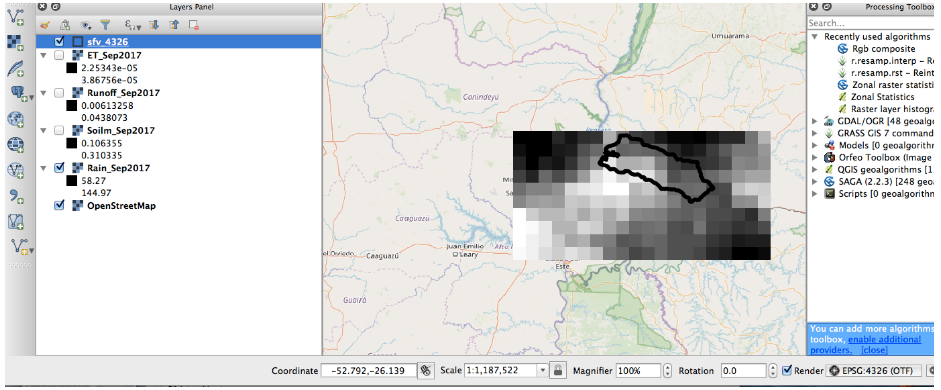
Freshwater Components Analysis in QGIS

3. From the top menu bar, click on **Web**, select **Open Layer Plugin** and select a background map
4. This exercise uses the plugin **OpenStreetMap**



Convert NetCDF Data to GeoTiff

5. In your QGIS map, click on the **Add Raster**  function on the left



6. Navigate to your saved Monthly Precipitation, Runoff, ET, and Soil moisture data Files and click on **Open** to add the files for September 2017. You can do this all at once by highlighting all the files.
   - A **Coordinate Reference System Selector** box may pop up. Select WGS84, EPSG 4326
   - From the top Menu Bar, you can zoom in and out on the layer

These NetCDF images have to be converted to GeoTIFF images for you to perform raster calculations on the data.

Add the SFV Shapefile

7. Click on the menu on the left bar and click **Add Vector** to add the SFV shapefile: sfv_4326.shp
8. To make the shapefile transparent with only the border left, right click on the layer file and go to **Properties** > **Style**
9. Click on the down arrow in the Fill window and select **Transparent fill**
10. Click on the down arrow in the **Outline** window and choose a color of the shapefile boundary (This example uses black)
11. Set the **outline width** to be 2.0
12. Click **OK** to get the following result in the QGIS window

Convert NetCDF Data to GeoTiff

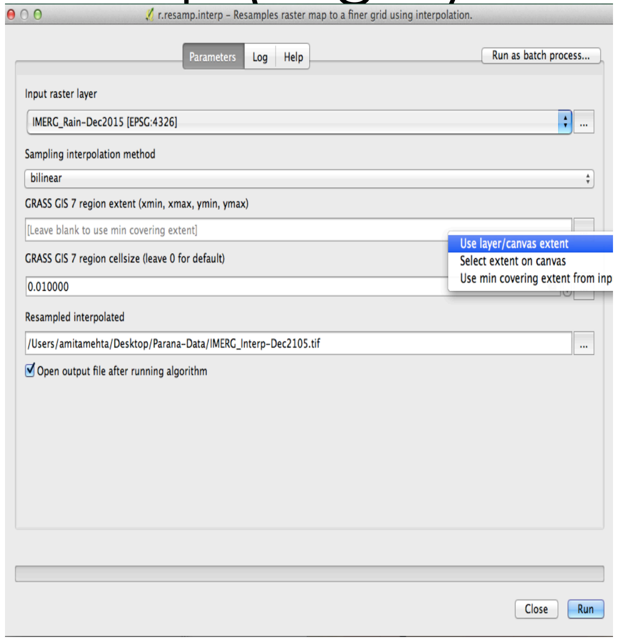
13. Right-click (or control-click on Mac) on the raster layer Rain_Sep2017
14. From the drop-down menu, select **Save As** – this will open a window
    - Note that **Format** in the window is **Gtiff**
    - Make sure the **Add save file to map** option is checked.
    - Click on **Browse** and enter the folder name where all the data are and enter a file name (Suggestion: Rain-Sep2017) and click on **Save**
    - You will see the GeoTiff layer displayed on the map and the file will be saved to the data folder
15. Repeat the above steps to convert all the NetCDF files to GeoTiff
    - You will have GeoTiff files for Soil Moisture, runoff, and ET
16. Now you can remove the NetCDF raster layers by right-clicking on each layer and choosing **Remove**

Resample Runoff Data

17. In the top menu, select **Processing** > **Toolbox.** A search window will appear to the right of the map. Enter **interp.**
    – You should see r.resamp.interp from the list
18. Double click on **r.resamp.interp** - this will open a window
19. In the **Input Raster Layer** window use the dropdown menu arrow to select Runoff_Sep2017 the raster layer
    – In the **Sampling interpolation method** window, choose **bilinear**
    – In the **GRASS GIS 7 region extern (xmin,xmax,ymin,ymax)** window, choose **Layer/canvas extent** from the dropdown menu
    – In the **GRASS GIS 7 region cellsize (leave 0 for default)** window enter the factor 0.1 (Note: we are interpolating to 10 km by specifying 0.1 cell size)

Resample Runoff Data

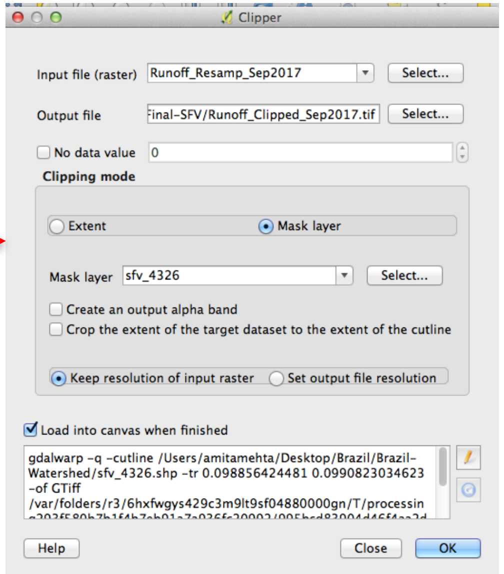
- In the **Resampled interpolated** window specify the folder and filename where the interpolated data will be saved
- Make sure that **Open output file after running algorithm** is selected
- Click on **Run** at the bottom right
- You will get a resampled interpolated data layer on the map (in gray colors)
- You will see a new layer: **Resampled interpolated**
- Renamed this layer
  - Suggest Runoff_Resamp_Sep2017

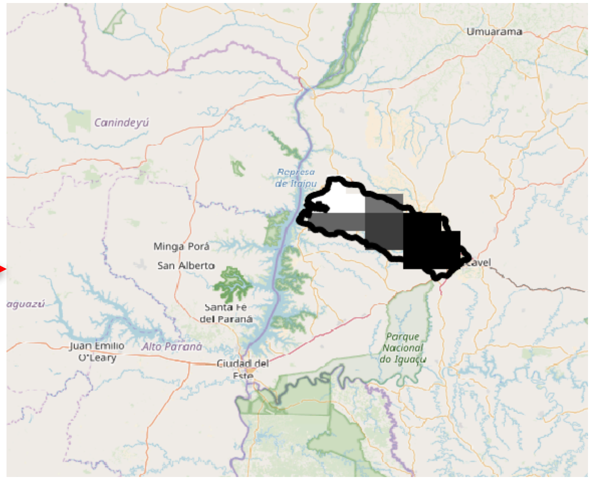


- Note: we used **nearest values** to resample, so increased resolution is not apparent in the map, but there are resampled data values at 0.1 degrees

Clip Runoff Data to the SFV Shapefile

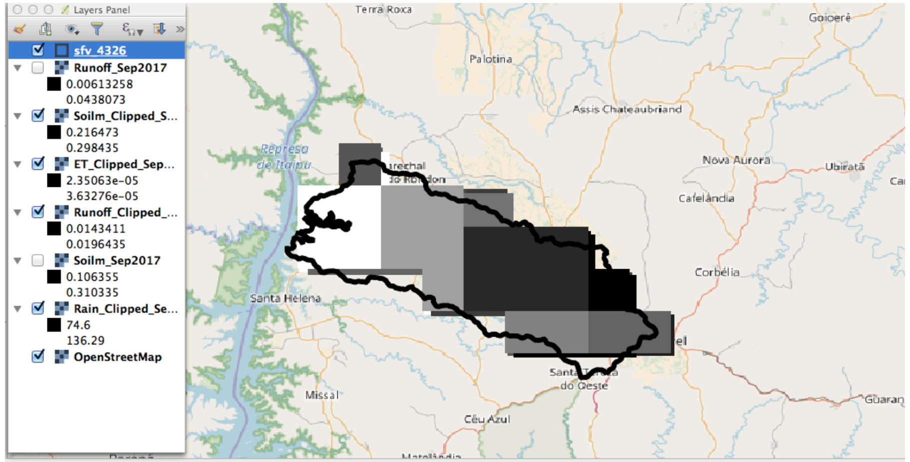
20. Now clip the interpolated rain layers to the SFV shapefile
    - On the top bar go to **Raster** > **Extraction** > **Clipper** to open the Clipper options window
    - In the Input File (raster) window select Runoff_Resamp_Sep2017
    - In the Output file window select output folder and enter file name (suggest Runoff_Clipped-Sep2017).
    - Check the **Mask Layer** and in the **Mask Layer** window select the shapefile name sfv_4326.
    - Click **OK** on at the bottom right. You will see the data clipped by the shapefile boundary





Resample and Clip ET and Soil Moisture Data to the SFV Shapefile

21. Repeat steps 17-19 for the ET and Soil Moisture data layers
    – You will have two, new resampled layers you can rename as ET_Resamp_Sep2017 and Soilm_Resamp_Sep2017
22. Repeat step 20 to clip the resampled ET and soil moisture layers to the SFV shapefile
    – You can rename the clipped layers as ET_Clipped_Sep2017 and Soilm_Clipped_Sep2017
23. Finally, repeat step 20 to clip the rain layer and name the layer Rain_Clipped_Sep2017

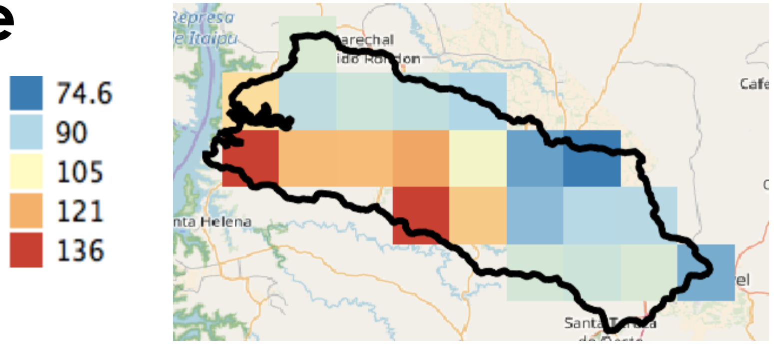


You will have all the fresh water components clipped to the SFV watershed, at 0.1 degree resolution

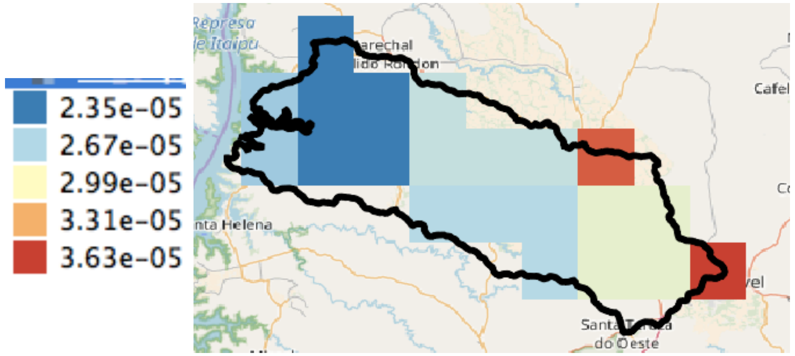
Add Color to Clipped Data Layers

24. Right click on the clipped file Rain_Clipped_Sep2017 and go to **Properties** > **Style**
    - Select the **Render Type** as **Singleband Pseudocolor**
    - Next to **Color**, make sure the Red-Yellow-Blue (RdYlBu) color palette is selected
    - Select **Invert** so that low runoff values are shown in blue and high in red
    - Keep the default **Min** and **Max** values
    - Below the color display, change the **Mode** to **Equal Interval** and **Classes** to 5. Click **Classify**. Click **Apply**

Rain



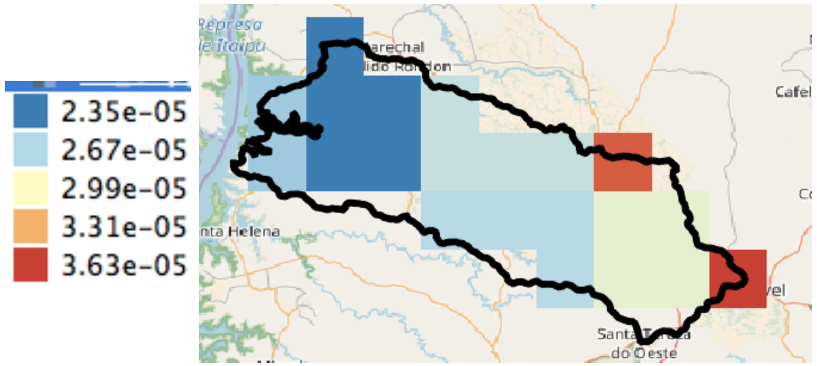
ET



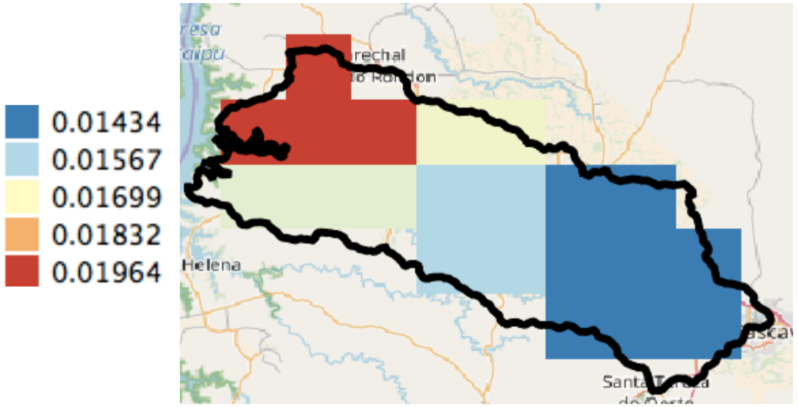
Add Color to Clipped Data Layers

25. Repeat step 24 for:
   - ET_Clipped_Sep2017
   - Runoff_Clipped_Sep2017
   - Solim_Clipped_Sep2017

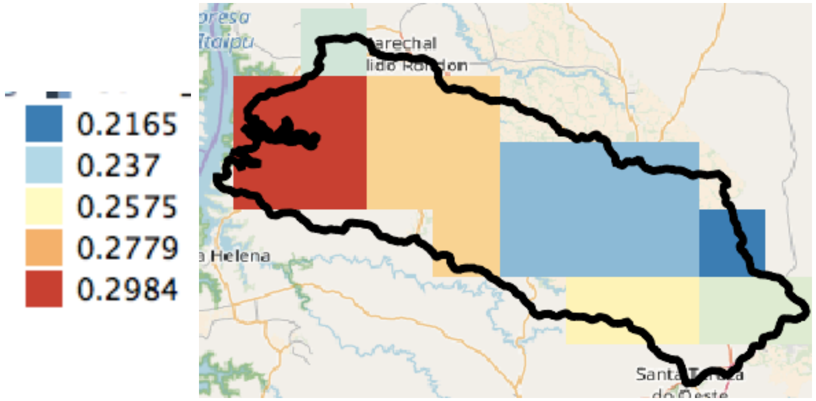
ET



Runoff

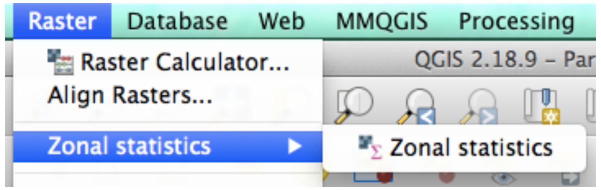


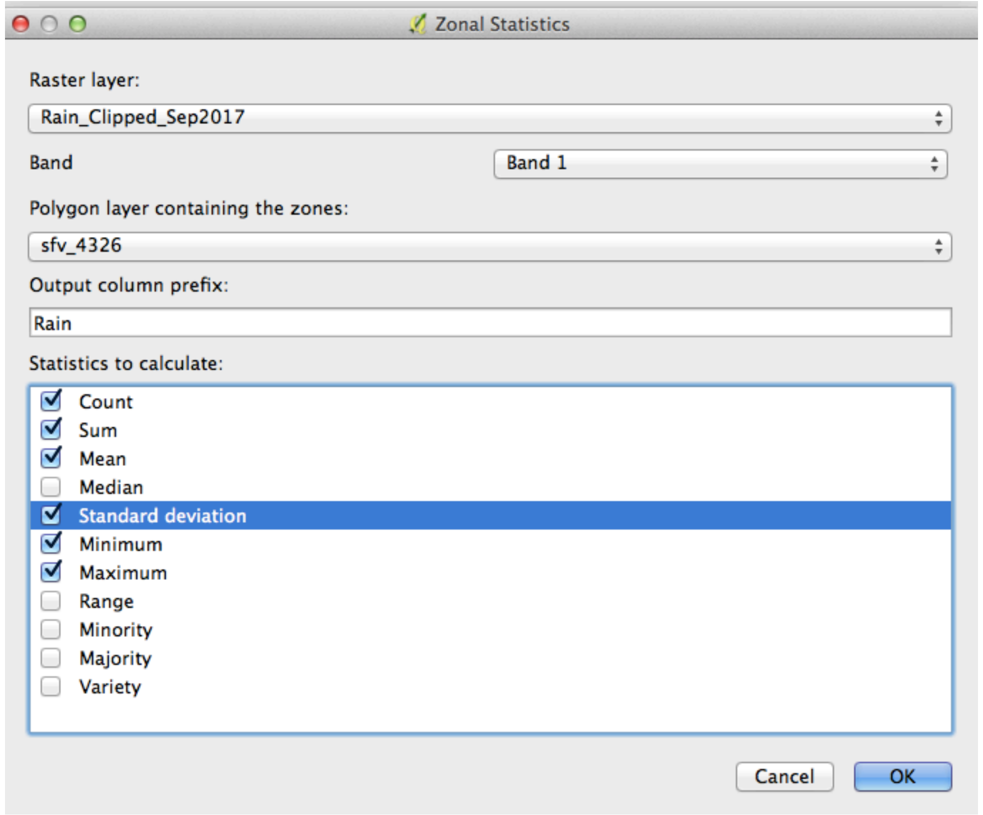
Soil Moisture



Calculate Total Freshwater Components for the SFV Watershed

26. On the top bar, select **Raster** > **Zonal Statistics** or search for **Zonal Statistics** in the **Processing Toolbox**
27. You will get the Zonal Statistics option window
28. In the **Raster Layer** window, select Rain_Clipped_Sep2017
29. In the **Polygon layer containing zone** window, make sure the sfv_4326 shapefile is selected
30. In the Output column prefix, enter **Rain** (or any name that you want to use to identify the statistics for this layer)





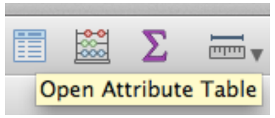
Calculate Total Freshwater Components for the SFV Watershed

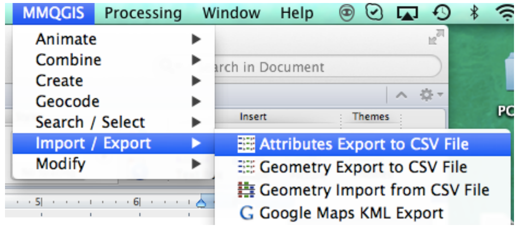
31. In the **Statistics to calculate** window, select **Count**, **Sum**, **Mean, Standard deviation**, **Minimum**, **Maximum**
32. Click **OK** on the bottom right
33. Repeat the above steps for:
    - ET_Clipped_Sep2017
    - Runoff_Clipped_Sep2017
    - Soilm_Clipped_Sep2017

- Remember to change the prefix. Suggestion: ET, Runoff, and Soilm

Calculate Total Freshwater Components for the SFV Watershed

48. The statistics will be available in the **Attribute Table** from the top bar or right click on the shapefile under the layers panel
    - Click on the Attribute Table and examine the numbers
    - You can copy the statistics **Mean, Standard Deviation, Minimum, and Maximum** for the 2015 and 2016 layers. **OR**
    - Save the attribute table as a CSV file by using the plugin MMQGIS. If you do not have this plugin, then follow the procedures you used to download and install the OpenLayers plugin on slide 22, but for MMQGIS
49. Use **MMQGIS** > **Import/Export** > **Attributes Export to CSV file** (Suggestion: save as Freshwater.csv)





Calculate Total Monthly Freshwater Components

50. Examine the statistics in the file Freshwater.csv showing data for all the components over the SFV watershed
    - The first row contains all the statistics for the freshwater components
    - You can rearrange the file in multiple columns by copying statistics for each freshwater component

subbacia	Raincount	Rainsum	Rainmean	Rainstdev	Rainmin	Rainmax
Rio SÃ£o Fra	22	2224.20004	101.100002	16.6940112	74.6000061	136.600021
	Etcount	ETsum	ETmean	ETstdev	ETmin	ETmax
	21	0.00057413	2.73E-05	3.30E-06	2.35E-05	3.63E-05
	Runoffcoun	Runoffsum	Runoffmean	Runoffstde	Runoffmin	Runoffmax
	21	0.33896112	0.01614101	0.00191602	0.01434108	0.01964883
	Soilmcount	Soilmsum	Soilmmean	Soilmstdev	Soilmmin	Soilmmax
	21	5.39734872	0.25701661	0.02549958	0.21647263	0.29851708

Calculate Total Monthly Freshwater Components

51. Use the mean of each water component from the Freshwater.csv file and convert all the components to kg/m^2 per month
    – Please see the appendix to understand how the unit conversion factor for each component is calculated

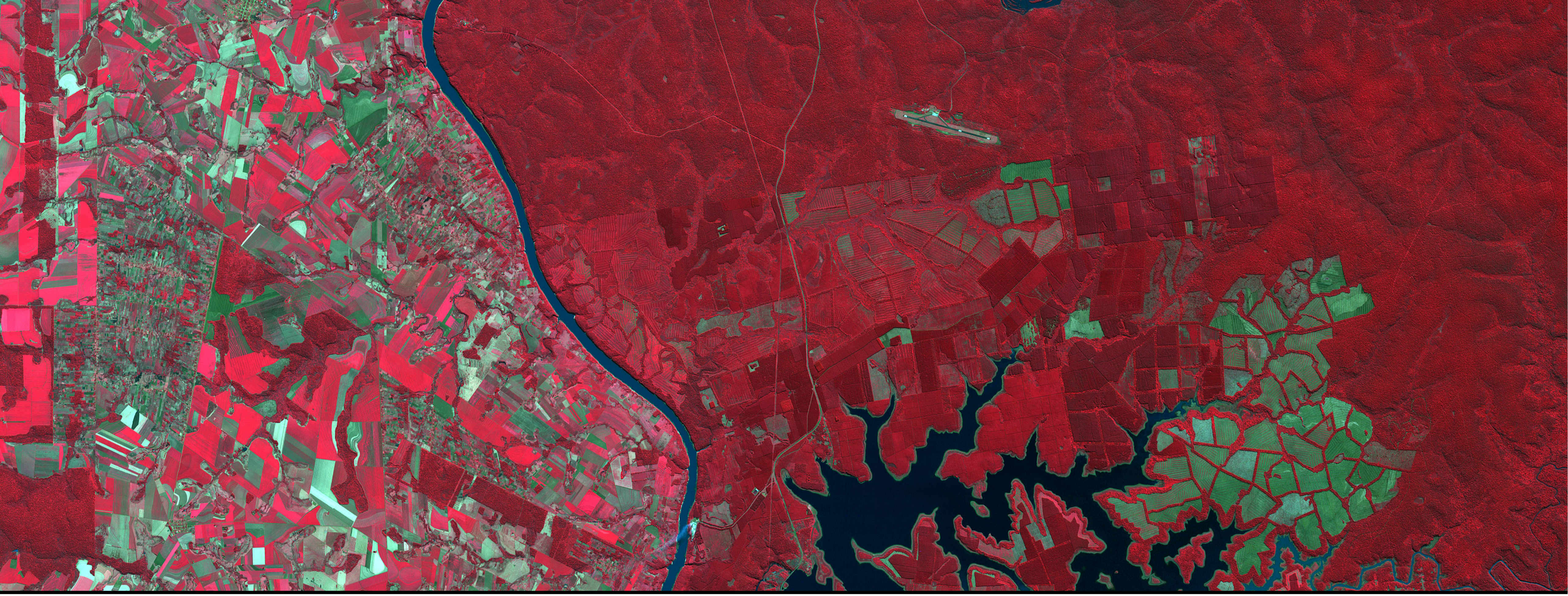
Freshwater Components for September 2017 over the SFV Watershed:

Rain = no conversion = 101 kg/m^2

ET = 2.73×10^{-5} * (3600 * 24 * 30) = 70 kg/m^2

Runoff = 0.016 * (8 * 30) = 3.84 kg/m^2

Soil Moisture = 0.26 * (10 * 30) = 78 kg/m^2 (in top cm of soil



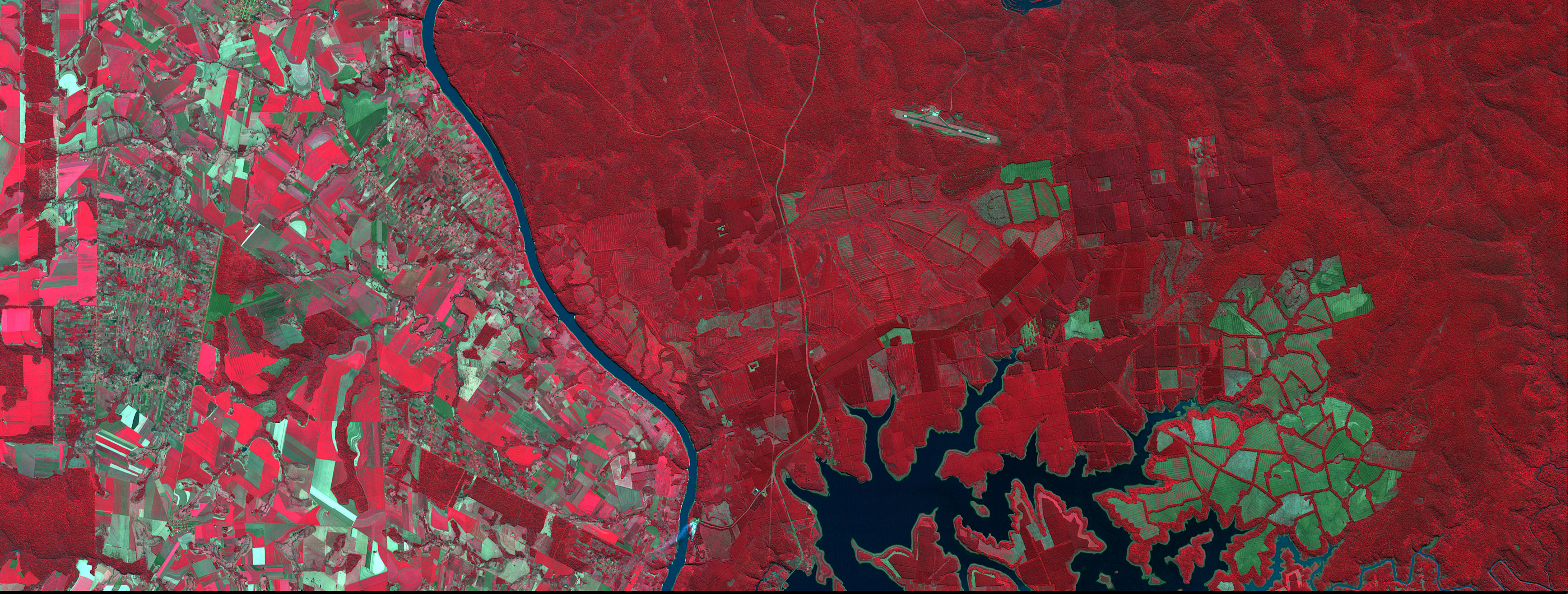
Discussion

Discussion Questions

1. Based on the QGIS maps, describe where high and low centers of rain, ET, Runoff, and soil moisture are.

2. Integrated over September, which water component has the largest impact over the SFV Watershed? Which one is the lowest?

3. Since we have the main freshwater components, is it possible to estimate water availability from them? Explain your answer.



Part 2

Part 2

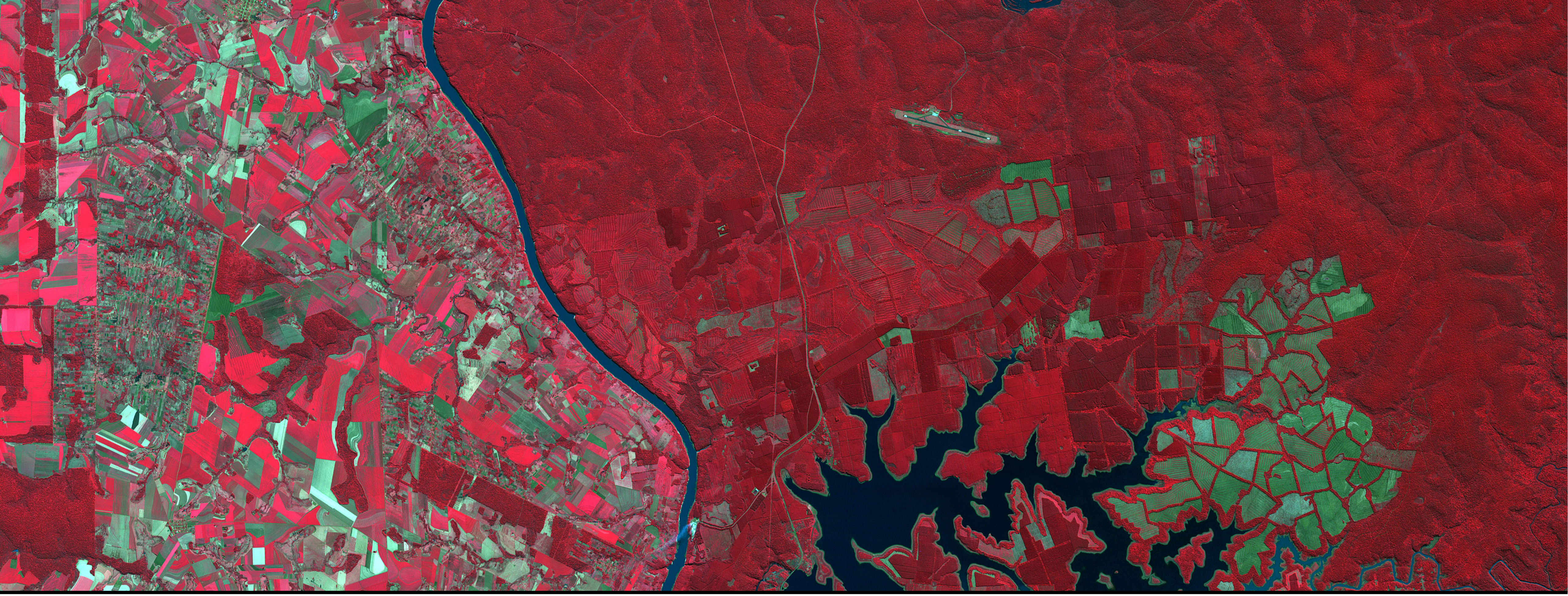
- This exercise will be conducted in a group of 5-6 members
- As a group, select a region of interest by using its shapefile. If you do not have the shapefile, you can use a rectangle encompassing your region of interest
- For the selected region, select a month from either 2016 or 2017 for a case study. We suggest choosing a period that you have information about flood or drought conditions for
- Follow the procedures in Part 1 to get freshwater components for your selected area and time period

Part 2

- We suggest distributing tasks within the group members
- Using the steps from Part 1, get the following data for your selected region and month of your case study:
  - GPM IMERG Precipitation using Giovanni
  - GLDAS Runoff and ET using Giovanni
  - SMAP Soil Moisture from Princeton Latin American Flood & Drought Monitor
  - Monthly accumulated freshwater components from QGIS
- **Optional:** If you have time, you can include SAR data, MODIS NDVI, and SRTM terrain data in your project based on previous exercises
- Save the results of your case study as PowerPoint slides to present to the larger group

Group Presentation

- Include:
  - names and affiliations for the group members
  - a map of the region for the case study
  - the time period of the case study
  - maps of the freshwater components you obtain from your analysis
  - values of freshwater components integrated over the study region and month
  - description of the freshwater components
  - a conclusion and summary



Appendix: Converting Units of Freshwater Components

Unit Conversion

- **Runoff:** data are kg/m^2: averaged over a month from 3 hourly data
  - Runoff per month = kg/m^2 * 8 times/day * 30 days/month
- **Soil Moisture**: data are in m^3/m^3: volume of water per unit volume of soil averaged over a month from daily values
  - m^3/m^3 of soil moisture = m^3/m^3 * (water density) = m^3/m^3 * (1000 kg/ m^3) = kg/ m^3 moisture = 10^3 kg/ m^2 * (10^3 mm)
  - Soil Moisture per month = (kg/m^2)/(mm/day) * 30 days

Unit Conversion

- We are going to use the following unit conversion to bring all the freshwater components to (kg/m^2)/month
- We will use water density = 1000 kg/m^3
- **Rain** data are mm/month: depth of water per unit area per month
  - mm/month * (water density) = mm/month * (1000 kg/m^3) = mm/month * (10^3 kg/(m^2*mm*10^3) = kg/m^2
- **ET** data are in kg/m^3 per second
  - ET/month = ET ((kg/m^2)/second)*(36000 seconds/hour) * (24 hours/day) * (30 days/month)